Stormwater BMP Performance Assessment and Cost Benefit Analysis

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Capitol Region Watershed District

Mississippi River Forum
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Saint Cloud and Saint Paul, Minnesota

Presentation Outline

- Watershed Districts and CRWD
- Project and Project Area
- BMPs Constructed
- Monitoring, Modeling, Removal Efficiency
- Operation and Maintenance
- Costs
- Cost Benefit

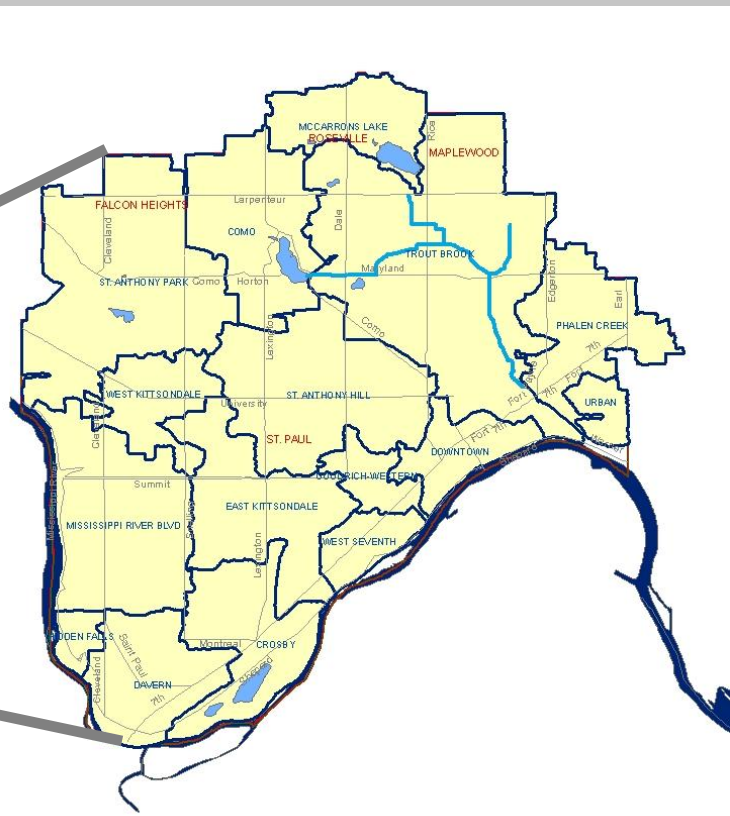
Watershed Districts

A Watershed District is a special purpose unit of local government

- Area based on watershed boundaries
- Purpose is to manage water resources
- MN Watershed law established in 1955
- 48 Watershed Districts throughout Minnesota
- Board of Managers appointed by County
- Funded through tax levy
- Regulatory authority
- Own & operate drainage systems

Capitol Region Watershed District

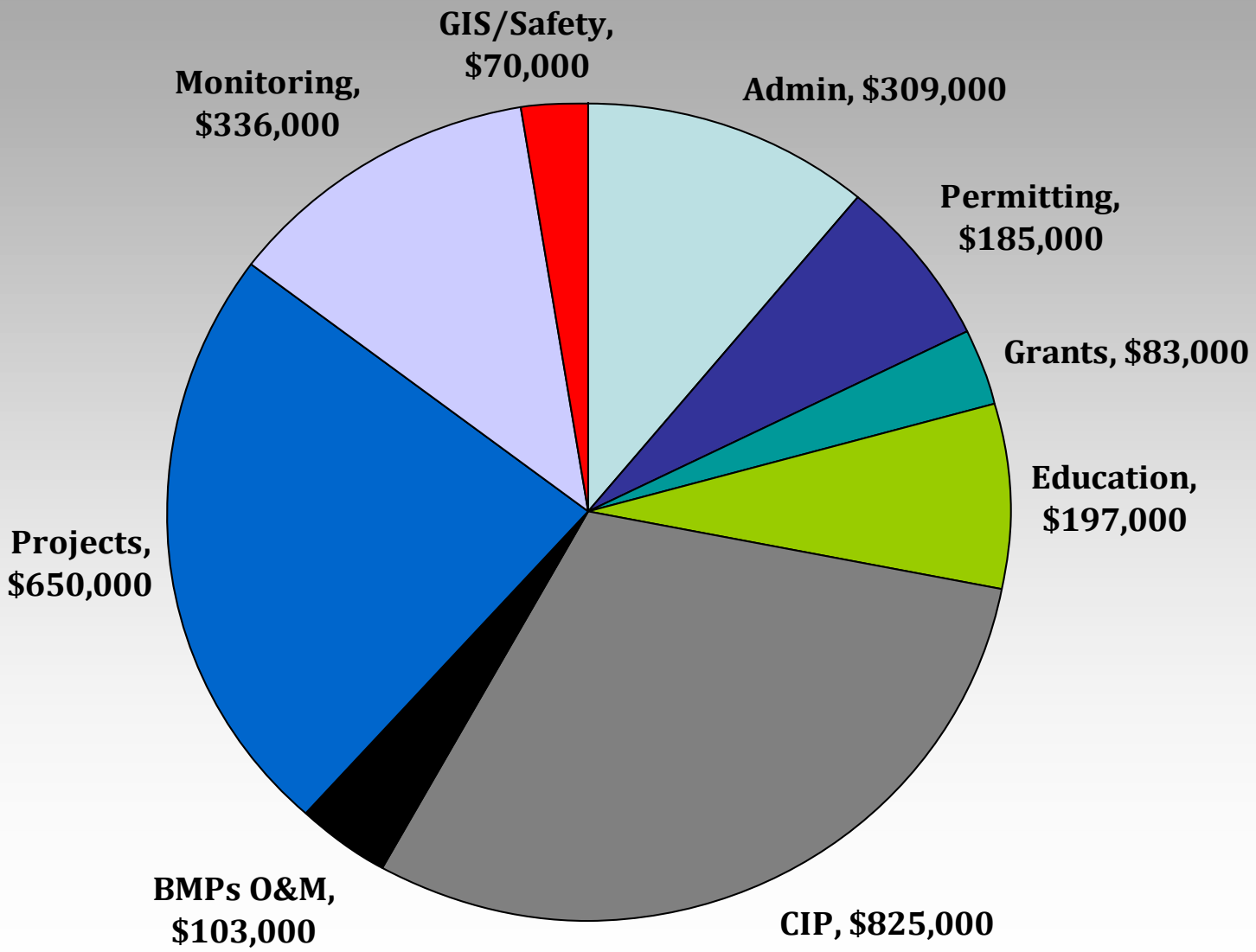
- 41 Square Miles (25,965 acres)
- Portions of 5 Cities
- 4 Lakes (Como, McCarrons, Crosby, Loeb)
- Numerous wetlands
- 5 member Board
- 12 staff
- Citizen Advisory Committee
- 2010 Budget $2.6 M
- Population 250,000



What does CRWD do?

- Water Quality Projects
- Permitting
- Monitor Surface Water
- Own & maintain 6 miles of Trout Brook Stormsewer
- Stewardship Grants
- Watershed Education
- GIS and Safety Programs

CRWD 2010 Budget, $2.6 M



Capitol Region Watershed District

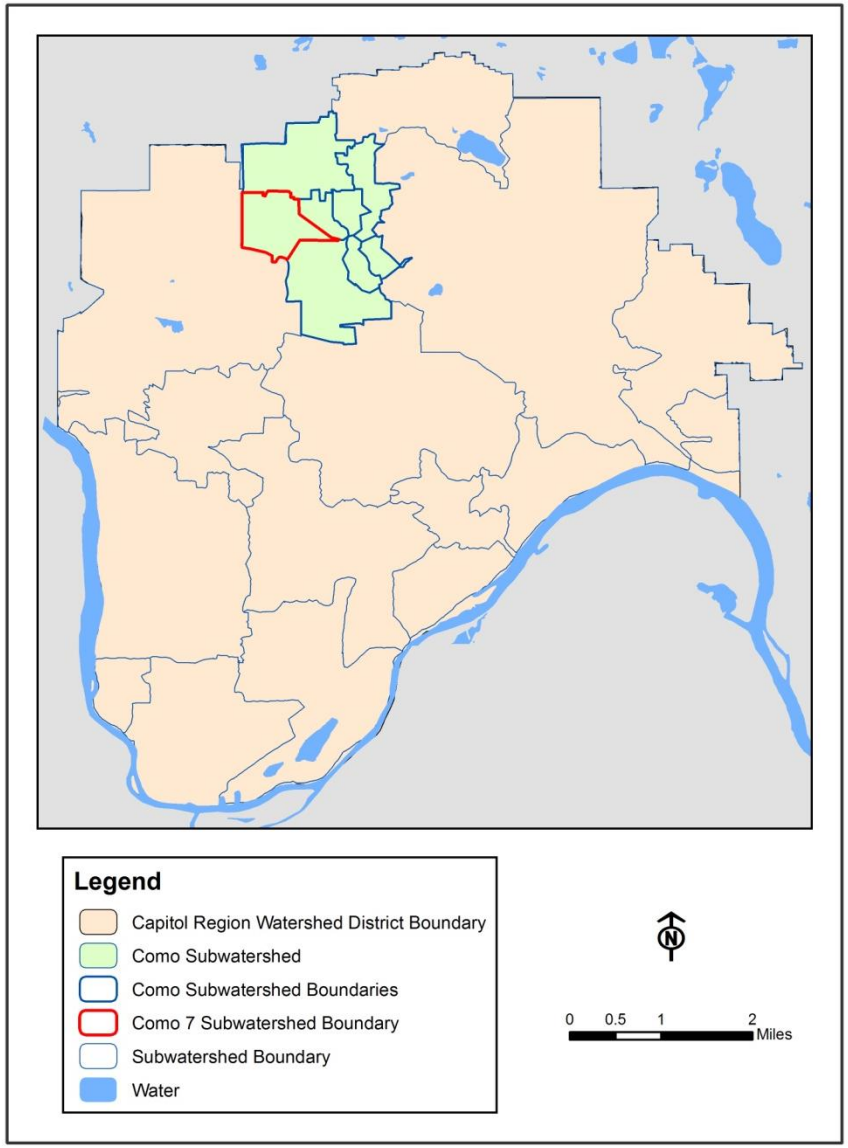
- People - 1/20 of Minnesotans
- Pavement – 42 % Impervious
- Pipes – virtually no natural channels
- Process – City Departments bigger than many cities

Capitol Region Watershed District

Drains to the Mississippi River

Arlington Pascal Stormwater Improvement Project

- Multi-Jurisdictional Project in the Como 7 Subwatershed
- Goals:
  - Reduce Flooding in the Como 7 and Adjacent Subwatersheds
  - Address Needed Storm Sewer Improvements
  - Improve Water Quality by Reducing the Amount of Phosphorous Discharging to Como Lake
  - Determine Equitable Distribution of Costs



Arlington Pascal Stormwater Improvement Project

- Original Project Cost: $2.5 Million
  - 60” Storm Sewer Pipe
  - No Water Quality Benefits
- Final Project Cost: $2.0 Million
  - 18 Stormwater BMPs
  - Stormwater Volume and Pollutant Reduction Benefits

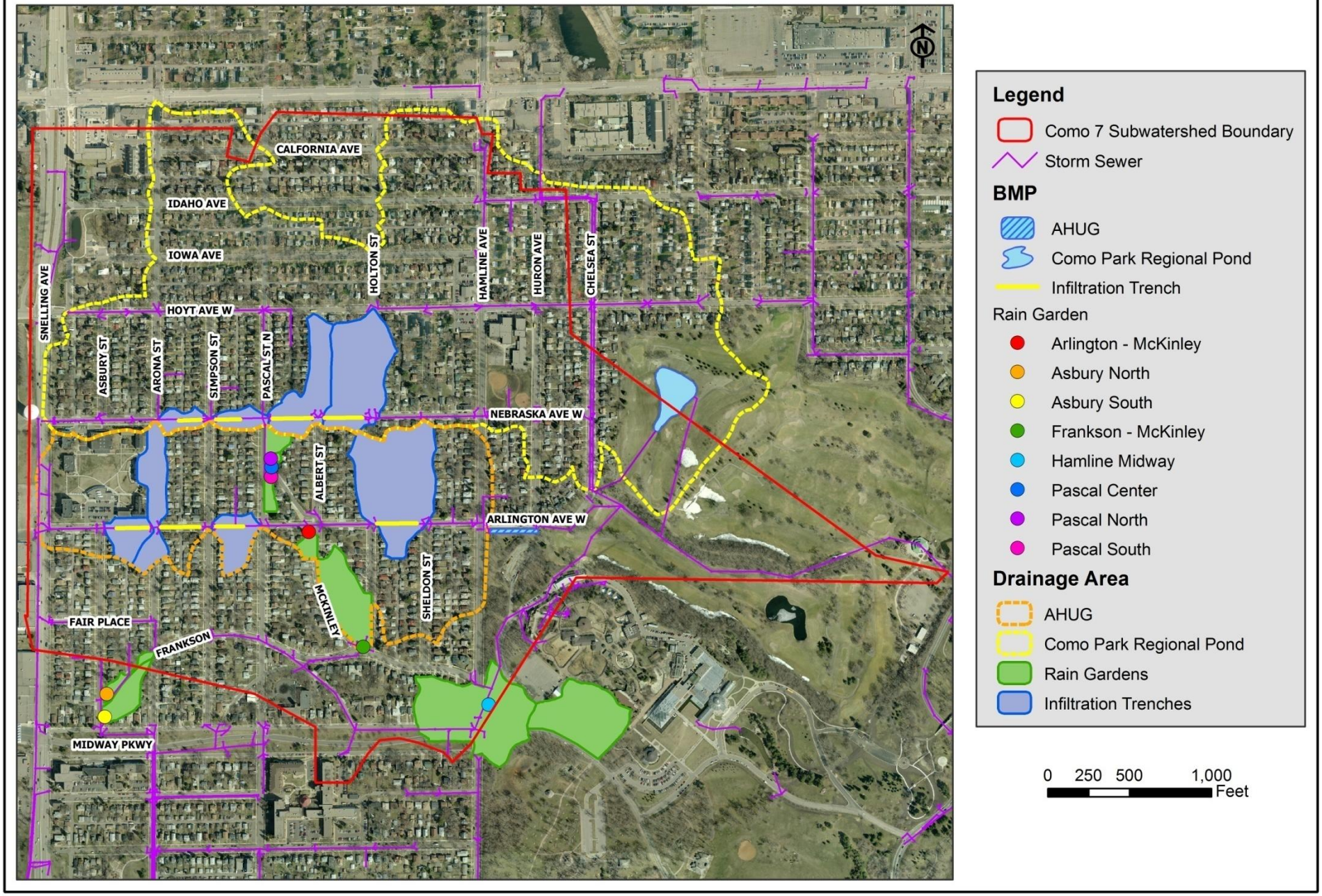
Stormwater BMPs Constructed

- Arlington Hamline Underground Stormwater Facility (AHUSF)
- Regional Stormwater Pond (Como Park Regional Pond)
- 8 Underground Infiltration Trenches
- 8 Rain Gardens

Stormwater BMPs

- Treatment Train of BMPs
- Total Drainage Area: 200 Acres
- Combined Storage Area: 141,553 ft^2
- Combined Storage Volume: 444,390 cf




CALFORNIA AVE
IDAHO AVE
IOWA AVE
HOYT AVE W
NEBRASKA AVE W
ARLINGTON AVE W
FAIR PLACE
FRANKSON
MIDWAY PKWY
SNELLING AVE
ASBURY ST
ARONA ST
SIMPSON ST
PASCAL ST N
HOLTON ST
ALBERT ST
MCKINLEY
SHELDON ST
HAMLINE AVE
HURON AVE
CHELSEA ST
N
Legend
Como 7 Subwatershed Boundary
Storm Sewer
BMP
AHUG
Como Park Regional Pond
Infiltration Trench
Rain Garden
Arlington - McKinley
Asbury North
Asbury South
Frankson - McKinley
Hamline Midway
Pascal Center
Pascal North
Pascal South
Drainage Area
AHUG
Como Park Regional Pond
Rain Gardens
Infiltration Trenches
0 250 500 1,000
Feet

Arlington Hamline Underground Stormwater Facility (AHUSF)

- Total Capital Cost: $799,000
- Storage Volume: 85,813 cf
- Drainage Area: 50 Acres
- 849 Feet of 10-Foot Diameter, Corrugated, Perforated Metal Pipes
- Vortech® Serves as a Pretreatment Unit
- Began Operation: Fall 2006

Como Park Regional Pond

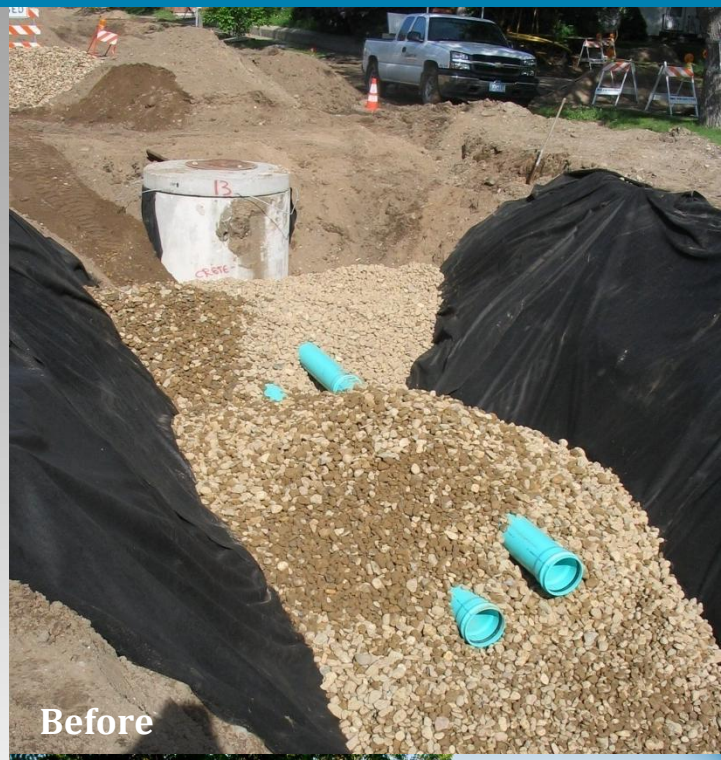
- Total Capital Cost: $1,364,000
- Storage Volume: 301,871 cf
- 128 Acres Direct Drainage Area
- Also Receives Discharges From Gottfried's Pit in Roseville (540 Acres)
- Began Operation: December 2007

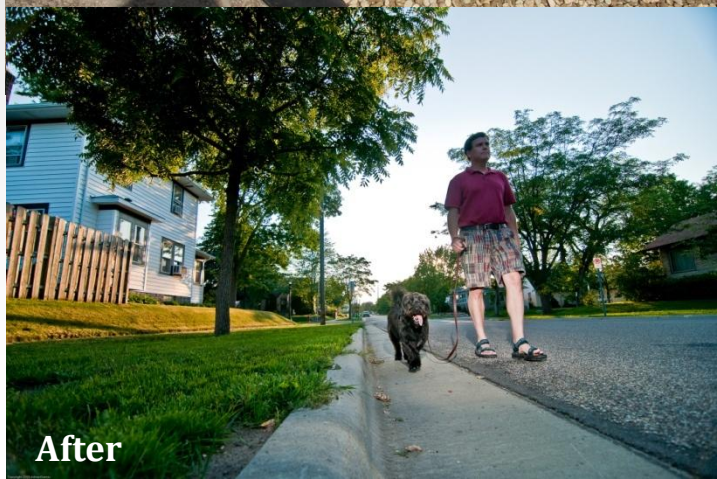

Normal Water Level


High Water Level

Underground Infiltration Trenches

- Total Capital Cost: $400,000
- Combined Storage Volume: 37,352 cf
- Combined Drainage Area: 23 Acres
- Comprised of an Aggregate Backfill with 2, 10-Inch Perforated Pipes
- 30 Sumped Catch Basins and 16 Sumped Manholes Serve as Pretreatment Units
- Began Operation: June 2007





Rain Gardens

- Total Capital Cost: $160,000
- Combined Storage Volume: 19,354 cf
- Combined Drainage Area: 16 Acres
- All Rain Gardens Were Operational in 2007

BMP Stormwater Monitoring

- 2007 and 2008
  - AHUSF
  - 2 Infiltration Trenches (Trenches 4 and 5)
  - 8 Rain Gardens
  - Como Park Regional Pond (2008)

BMP Monitoring Methods

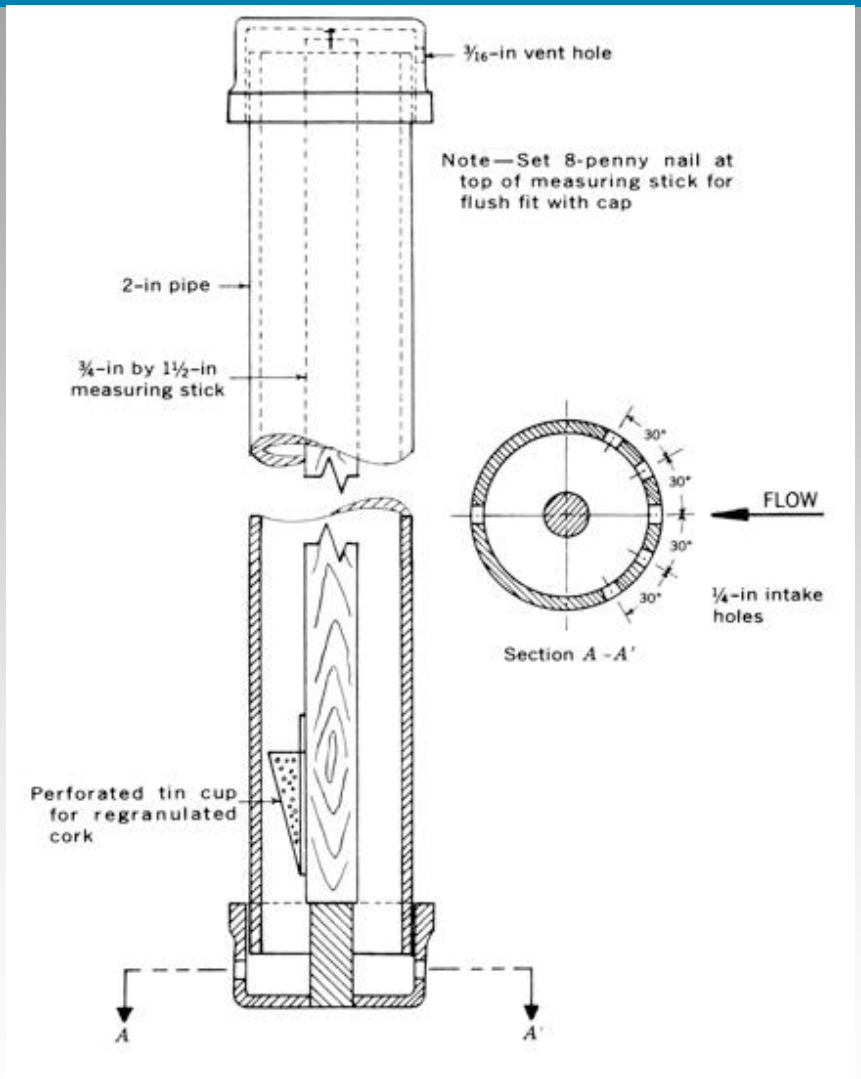
- Inlet and Outlet Monitored (except Rain Gardens)
  - Continuous Water Level and Flow Recorded Every 10 Minutes
  - Water Quality Samples Collected During Storm Events
- For Each Storm Event and Monitoring Season:
  - Determined Total Flow and Calculated Total Phosphorous (TP) and Total Suspended Solids (TSS) Loads
- Also Determined Total Solids Loads Removed

Rain Garden Monitoring

- Manual Crest Gauges
  - Installed at the Lowest Point in Each Garden
  - Measured Peak Water Level Reached During a Storm Event

Crest Gage

- www.rickly.com
- Ground cork
- Floats to hwl



Total Solids Load

- Sum of:
  - Total "TSS" Load Removed by BMP
  - **Suspended Solids** Captured by BMP
  - **Gross Solids** Captured by Pretreatment Units

Gross Solids are Particles Larger than Suspended Size >75 um (Debris Such as Floatables, Organic Matter, and Course Sediment).

- Gross Solids were **Measured** in Pretreatment Units for AHUSF and Infiltration Trenches
- Gross Solids Captured by Rain Gardens and Como Park Regional Pond Were **Estimated**

Model Methods

- 2007 & 2008 Field Monitoring Date
  - Captured 7-8 months annual data
- Model complete year for 2007 & 2008
  - P-8 Urban Catchment Model - Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds, William W. Walker, Jr. PhD.
  - Simulated the Performance of Each BMP over an Entire Year
  - Total Discharge and TP and TSS Loads
  - Calibrated Using Actual Precipitation and BMP Monitoring Data
- Model "typical" year for projected annual load
  - Annual Results for 2007, 2008, and an Average Precipitation Year 1993 (Projected Annual)

P8 Model

- Calibrated Using Actual Precipitation Data and BMP Monitoring Data
- Annual Results for 2007, 2008, and an Average Precipitation Year – 1993 (Projected Annual)

Model Results

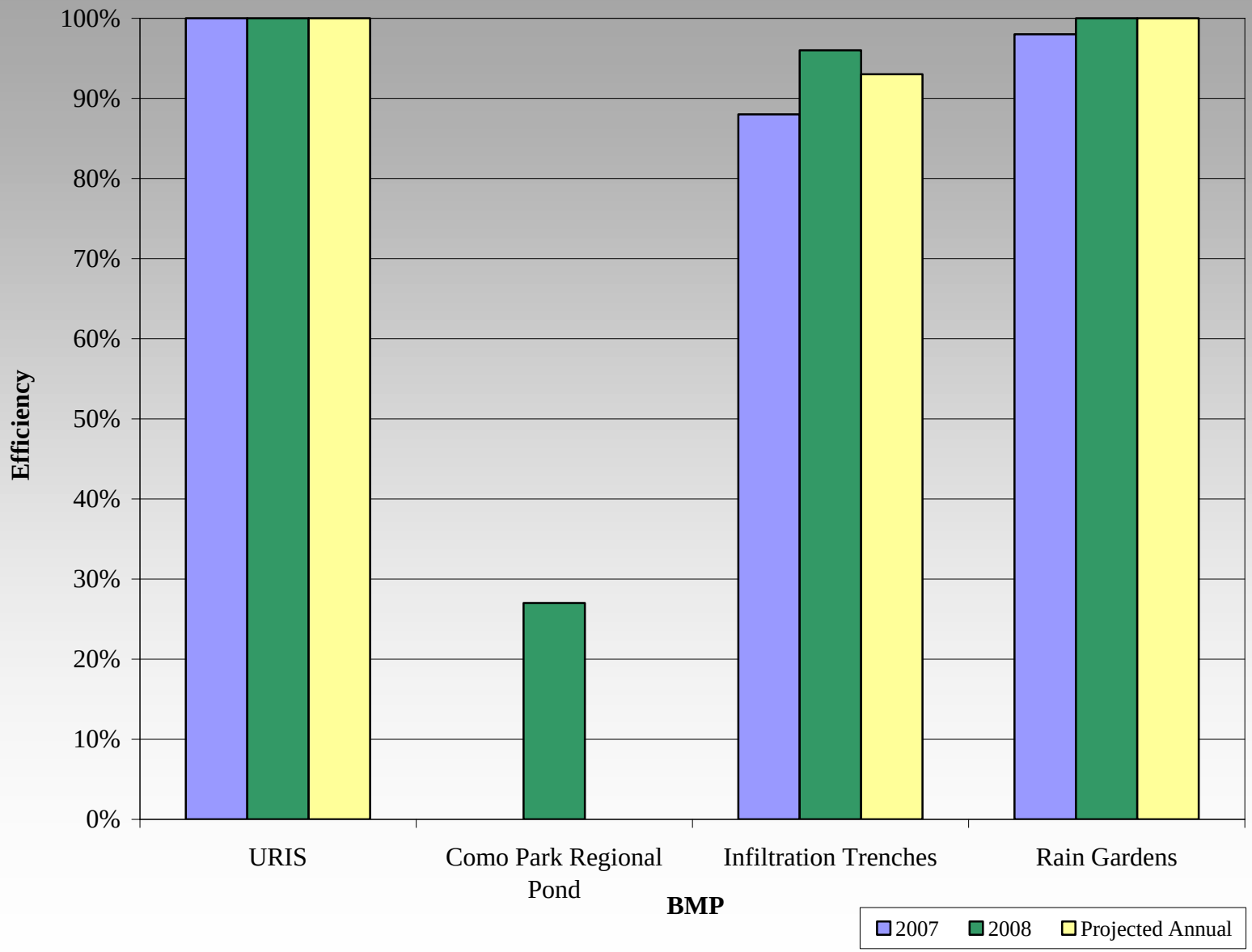
- Pollutant Removal Efficiencies
- % Removal
- Parameters Modeled
  - Volume
  - TP
  - TSS

Modeled Performance Efficiencies

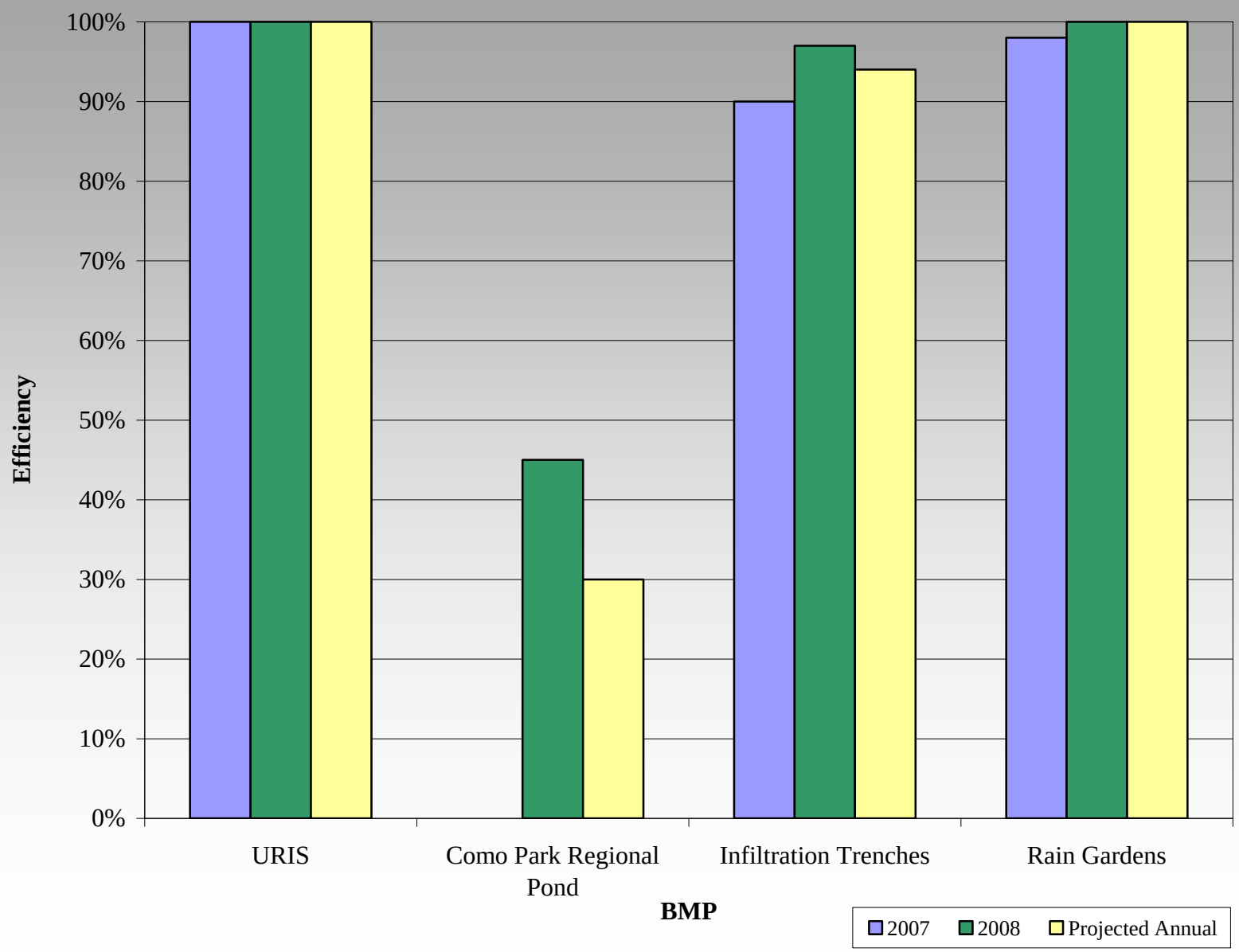
		Arlington-Hamline Facility	Como Park Regional Pond	Infiltration Trenches	Rain Gardens
2007	Volume	100%	NA	88%	98%
	TP	100%	NA	90%	98%
	TSS	100%	NA	94%	98%
2008	Volume	100%	27%	96%	100%
	TP	100%	45%	97%	100%
	TSS	100%	83%	98%	100%
Projected Annual	Volume	100%	0%	93%	100%
	TP	100%	30%	94%	100%
	TSS	100%	78%	96%	100%

NA: Not Applicable

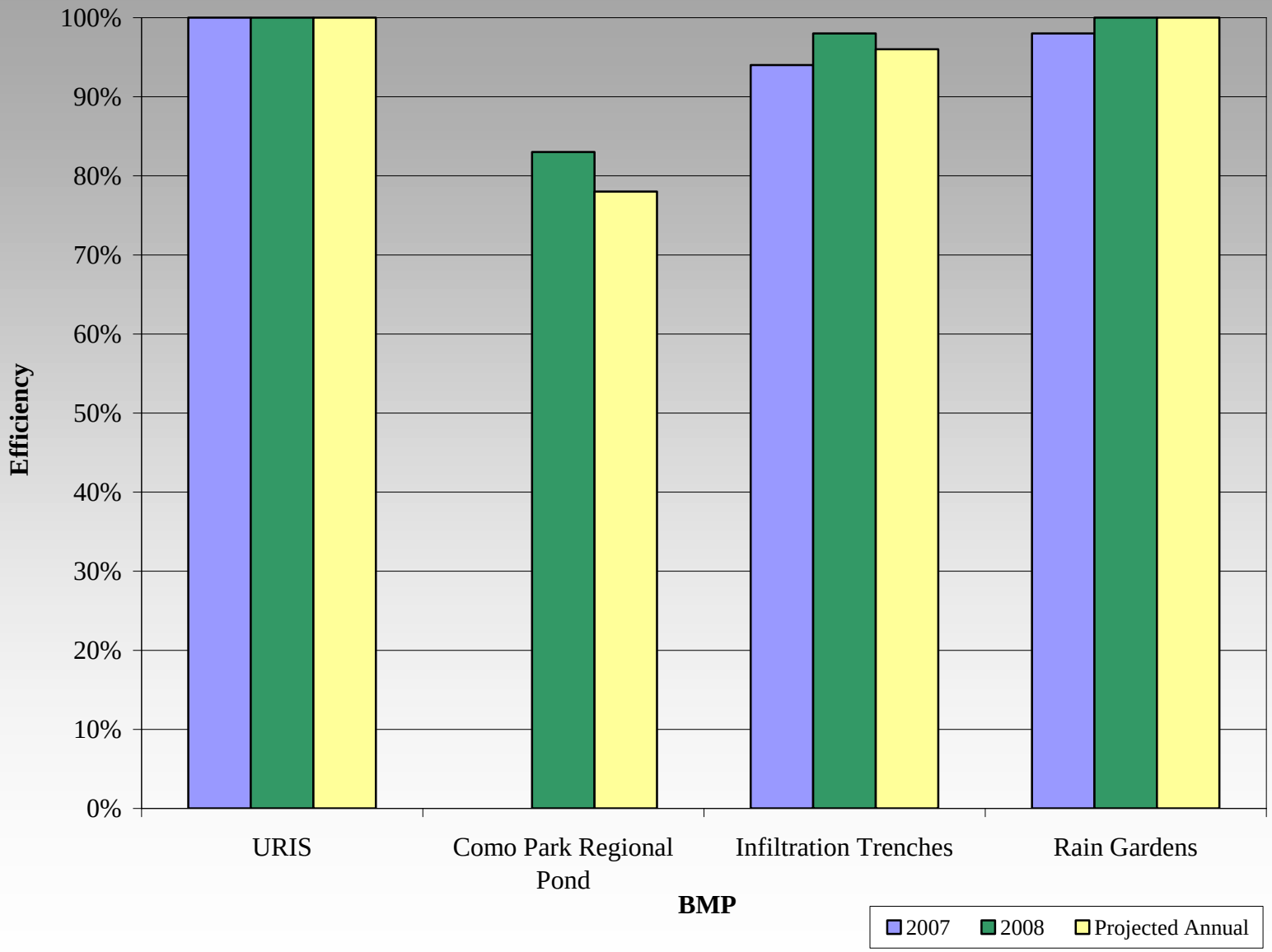
Volume Reduction Efficiencies



TP Removal Efficiencies



TSS Removal Efficiencies



BMP Operation and Maintenance

- Inspection and Maintenance Protocols
- Document Using Electronic Field Forms (PDA)
  - BMP, Activity, Staff, Time
- Staff Hours and Costs Used to Calculate Labor Costs
- Determined Annual Operation and Maintenance Costs
  - 2007, 2008, Projected Annual Year

BMPs Maintained

2007 and 2008

- AHUSF
  - Vortech® Unit
- 8 Infiltration Trenches
  - 30 Sumped Catch Basins
  - 16 Sumped Manholes
- 8 Rain Gardens
- Como Park Regional Pond (2008 only)

Operation and Maintenance Results

- Inspection and Maintenance Activities
- O & M Costs
  - 2007, 2008, Projected Annual
- O & M Hours

AHUSF

2007, 2008, and Projected Activities:

- Pipe Gallery Inspections
- Vortech® Sediment Inspections
- Manhole Sediment Inspections
- Debris Removal From Vortech® Unit

Projected Activities:

- Debris Removal From Pipe Gallery

Como Park Regional Pond

2008 and Projected Activities:

- Sluice Gate and Gate Valve Maintenance
- Debris Removal From Pond Perimeter and Outlet Structure
  - Completed by City of St. Paul

Projected Activities:

- Bathymetric Survey of Pond
- Debris Removal From Pond (Dredging)

Infiltration Trenches

2007, 2008, and Projected Activities:

- Manhole and Catch Basin Sediment Inspections
- Post-Rain Trench Infiltration Inspections
- Debris Removal From Sumped Catch Basins and Manholes
- Catch Basin Hood Inspections and Gasket Replacement

Projected Activities:

- Jet Out and Remove Debris Accumulated in Perforated Pipes

Rain Gardens

2007, 2008, and Projected Activities:

- Monthly Inspections
- Post-Rain Inspections
- Maintenance
  - Mulching, Weeding, Mowing, Leaf Removal

Operation and Maintenance Results

	2007				
	Operation and Maintenance Costs	Labor	Equipment and Materials	Contract Services	Hours
AHUG	$531	$267	$264	$0	13
Como Park Regional Pond	NA	NA	NA	NA	NA
Infiltration Trenches	$5,509	$2,373	$0	$3,136	138
Trench 1	$336	$146	$0	$190	NA
Trench 2	$401	$211	$0	$190	NA
Trench 3	$1,062	$492	$0	$570	NA
Trench 4	$1,044	$475	$0	$570	NA
Trench 5	$645	$168	$0	$478	NA
Trench 6	$595	$215	$0	$380	NA
Trench 7	$383	$193	$0	$190	NA
Trench 8	$1,043	$473	$0	$570	NA
Rain Gardens	$14,851	$11,469	$2,621	$761	640
Arlington-McKinley	$1,735	$1,380	$293	$62	71
Asbury North	$1,541	$1,171	$307	$62	60
Asbury South	$1,500	$1,130	$307	$62	60
Frankson-McKinley	$2,097	$1,713	$322	$62	93
Hamline Midway	$1,266	$800	$140	$326	45
Pascal Center	$3,858	$3,118	$678	$62	187
Pascal North	$1,149	$815	$272	$62	49
Pascal South	$1,705	$1,342	$301	$62	77
APSIP Total:	**$20,891**	**$14,109**	**$2,885**	**$3,897**	**791**

[a]Includes staff, volunteer, and City of Saint Paul hours.

[b]Estimations based on staff observations. Contract services includes irregular maintenance activities amortized over the life expectancy of

NA: Not Available

Operation and Maintenance Results

	Projected Annual[b]			
	Operation and Maintenance Costs	Labor	Equipment and Materials	Contract Services
AHUG	$2,867	$282	$0	$2,586
Como Park Regional Pond	$4,550	$900	$50	$3,600
Infiltration Trenches	$12,339	$1,000	$100	$11,239
Trench 1	$1,125	$50	$5	$1,070
Trench 2	$1,152	$75	$7	$1,070
Trench 3	$2,079	$221	$22	$1,836
Trench 4	$2,074	$216	$22	$1,836
Trench 5	$1,141	$65	$6	$1,070
Trench 6	$1,548	$87	$9	$1,453
Trench 7	$1,150	$73	$7	$1,070
Trench 8	$2,071	$214	$21	$1,836
Rain Gardens	$5,803	$3,860	$1,243	$700
Arlington-McKinley	$486	$347	$139	$0
Asbury North	$612	$524	$89	$0
Asbury South	$655	$536	$119	$0
Frankson-McKinley	$645	$574	$70	$0
Hamline Midway	$1,602	$700	$202	$700
Pascal Center	$793	$397	$396	$0
Pascal North	$474	$387	$87	$0
Pascal South	$535	$395	$140	$0
APSIP Total:	**$25,559**	**$6,041**	**$1,393**	**$18,125**

[a]Includes staff, volunteer, and City o

[b]Estimations based on staff observati

NA: Not Available

Annual O & M Costs

- Total Cost of Labor, Equipment and Materials, and Contract Services

	2007	2008	Projected Annual
URIS	$531	$2,025	$2,867
Como Park Regional Pond	NA	$6,558	$4,550
Infiltration Trenches	$5,509	$12,405	$12,339
Rain Gardens	$14,851	$7,544	$5,803
APSIP Total:	$20,891	$28,532	$25,559

O & M Hours

	2007	2008
URIS	13	14
Como Park Regional Pond	NA	78
Infiltration Trenches	138	88
Rain Gardens	640	406
APSIP Total:	791	585

Cost-Benefit Analysis

- Costs
  - Annual Capital Costs
  - Annual Operating Costs
- Pollutant Removal Costs ($/unit)
  - Volume Reduction Costs
  - TP Removal Costs
  - Total Solids Removal Costs

Cost-Benefit Analysis

- **Volume Reduction and Pollutant Removal Costs ($/cf, $/lb)**
  - **Annual Operating Cost / Volume or Pollutant Reduction**

Reference Document:

A Public Works Perspective Regarding Cost vs. Benefit for Various Stormwater Best Management Practices (BMPs) Utilized to Manage Stormwater

(Minnesota Public Works Association, 2007)

Annual Capital Costs

- Total Capital Cost Amortized Over 35 Years

	2007	2008	Projected Annual
URIS	$24,605	$24,605	$24,605
Como Park Regional Pond	NA	$38,981	$38,981
Infiltration Trenches	$11,430	$11,430	$11,430
Rain Gardens	$4,578	$4,578	$4,578
APSIP Total:	$40,614	$79,595	$79,595

Annual Operating Costs

- Sum of Annual O & M Cost and Annual Capital Cost

	2007	2008	Projected Annual
URIS	$25,136	$26,630	$27,473
Como Park Regional Pond	NA	$45,539	$43,531
Infiltration Trenches	$16,939	$23,835	$23,769
Rain Gardens	$19,429	$12,122	$10,381
APSIP Costs:	$61,505	$108,127	$105,154

Volume Reduction Costs

- Annual Operating Cost ($) / Volume Reduction (cf)

	2007	2008	Projected Annual
URIS	$0.03	$0.07	$0.05
Como Park Regional Pond	NA	$0.02	NA
Infiltration Trenches	$0.02	$0.03	$0.03
Rain Gardens	$0.06	$0.07	$0.04
APSIP Costs:	**$0.03**	**$0.03**	**$0.06**

TP Removal Costs

- Annual Operating Cost ($) / TP Load Removed (lbs)

	2007	2008	Projected Annual
URIS	$1,007	$2,517	$1,828
Como Park Regional Pond	NA	$888	$714
Infiltration Trenches	$1,126	$2,221	$1,909
Rain Gardens	$3,494	$4,329	$2,791
APSIP Costs:	**$1,350**	**$1,434**	**$1,140**

Total Solids Removal Costs

- Annual Operating Cost ($) / Total Solids Load Removed (lbs

	2007	2008	Projected Annual
URIS	$0.36	$0.55	$0.54
Como Park Regional Pond	NA	$0.23	$0.21
Infiltration Trenches	$0.22	$0.61	$0.60
Rain Gardens	$0.37	$0.46	$0.39
APSIP Costs:	**$0.31**	**$0.35**	**$0.32**

MN Chapter APWA

Summary of Findings

BMP	Phosphorus	TSS	Volume
NURP Basin	$1,554/lb	$25/lb	$6,936/ac-ft
Raingarden (1)	$8,715/lb	$15/lb	$5,259/ac-ft
Raingarden (2)	$2,460/lb	$6.70/lb	$2,000/ac-ft
Water Reuse/ Irrigation	$533/lb	$1.20/lb	$450/ac-ft
Wastewater Plant	$220/lb	$0.57/lb	No Benefit
Flocculation	$280/lb	$0.60/lb	No Benefit
Underground Devices	$830/lb	$1.30/lb	No Benefit

Peer Review Comments

- **Who Commented?**
  - Bruce Wilson, Minnesota Pollution Control Agency
  - Ed Matthiesen, Wenck & Associates, Inc.
  - John Gulliver & Andy Erickson (UMN St. Anthony Falls Research Lab)
  - City of St. Paul

Peer Review Comments

- Overall Positive Feedback
- Clarify and Simplify Executive Summary
  - BMP Flow Network Diagram
- Majority of Comments were related to Expanding the BMP Assessment
  - Future Work – Incorporated into the Conclusions Section

Peer Review Comments: Future Work

- Volume Reduction due to Evaporation
- Removal Efficiencies of Pretreatment Units
  - Are they performing as expected? (e.g. Vortech unit)
- Recommend modifications
  - Improve efficiency, reduce maintenance, improve gross pollutant capture
- Compare BMP performances to other BMPs of similar type and size
- What, if any, affects does this infiltration have on ground water resources?

Conclusions

- BMP stormwater monitoring is important
  - Monitor actual BMP performance
  - Model calibration
- Overall, BMPs are performing as or better than expected
- Properly **designed**, **constructed**, and **maintained** BMPs are exhibiting high volume reduction and pollutant removal efficiencies

Conclusions (Cont.)

- Costs are largely affected by volume and pollutant load reductions
- Pond had the lowest costs, however, this type of BMP is not appropriate for all situations
  - Other BMP types have additional benefits which are not considered in cost calculations, ie, volume reduction.
- More studies are needed for urban stormwater BMPs which have this type of comprehensive analysis
  - Monitoring Data, Modeled Data, Capital Costs, O & M Costs
- Incorporate results into International BMP DB
- Perform maintenance consistent with U of M – St. Anthony Falls Laboratory protocols (Stormwater Assessment and Maintenance Project) http://stormwater.safl.umn.edu/

So…What does it cost to clean up a lake?

- Como Lake – Impaired - 250 # TP Removal required under approved TMDL.
- Capitol - $2,000,000 million to reduce 58# TP
- Therefore $8,600,000 to achieve required TP reductions in TMDL. Plus annual O&M.
- Source control, good housekeeping, private redevelopment projects AND CIP will be required to make clean up possible
- Clean Water, priceless

CRWD Reports

Villa Park

Villa Park Wetland Management Plan

Villa Park Wetland Management Plan Appendices

Education Reports

2009 Education and Outreach Plan

2009 Wilder Research Survey Results

2006 Monitoring Report

2005 Monitoring Report

Watershed Management Plan

2000 Watershed Management Plan

Subwatershed Analysis Reports

Como 7 Subwatershed Analysis Report

Lake Management Plans

Como Lake Management Plan

Lake McCarrons Management Plan

Loeb Lake and Willow Reserve Management Plan

Stormwater Pollution Prevention Program Reports

2009 CRWD SWPPP Annual Report

2008 CRWD SWPPP Annual Report

2007 CRWD SWPPP Annual Report

Wetland Assessment Reports

2007-2008 Wetland Assessment Report

Stormwater Best Management Practice Performance Assessments

2007 & 2008 Stormwater BMP Performance Assessment and Cost-Benefit Analysis

Questions

Stormwater BMP Performance Assessment and Cost-Benefit Analysis

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